Status of the Lees Ferry rainbow trout fishery with additional input regarding potential impacts of the 2008 High Flow Experiment

2008 Annual Report

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Cooperative Agreement No. 05WRAG0050 – Mod 5

January 2009

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EXECUTIVE SUMMARY

We present results of rainbow trout monitoring in the Lees Ferry tailwater (Colorado River below Glen Canyon Dam, AZ) during 2008. We also describe modifications made to monitoring strategies and techniques which were implemented to improve long-term monitoring programs. Objectives and subsequent findings are as follows:

Objective 1: *Evaluate data from fixed and random transects to determine if data can be pooled thereby increasing power to detect trends in the rainbow trout population.*

Fixed sites provide long-term trend data for monitoring fish populations in the Lees Ferry tailwater. Beginning in 2002, we implemented an augmented, serially alternating sampling design which incorporates random sites with the fixed sites to provide improved point estimates of fishery status. However, for statistical analyses it is unclear as to whether the two types of data can be combined for more powerful evaluation of long-term trends. To evaluate differences in means and variances of the two types of data, we compared catch-per-unit-effort (CPUE), relative condition (K_n) and size structure, (PSD; # fish ≥ 406 mm TL/# fish ≥ 305 mm TL)*100 from fixed and random sites during 2008 using one-way analysis of variance (ANOVA; S. Urquhart, *personal communication*).

Objective 2: *Monitor the trout fishery in the Lees Ferry reach to determine status and trends in abundance (CPUE), population structure (size composition and proportional stock density, PSD), growth rate and relative condition (K_n).*

Data collected during 2008 indicate the Lees Ferry fishery may return to a state similar to that observed from 1997-2001 where density-dependent constraints appeared to limit food and space availability. Relative abundance of fish increased in 2008, particularly fish < 200 mm, and are similar to the highest observed on record. Relative condition was lower in 2008 than in 2007 and is likely a result of increased fish densities. The size structure of the rainbow trout population remains low but has shown an increasing trend since 2006. Similarly, angler catch rates have shown an increasing trend since 2006 and currently resemble the catch rates observed during the early 1990's. Future monitoring over the next few years should reveal how the fishery indices respond

to a high flow experiment and a fall stable flow regime, all of which occurred during 2008.

Objective 3: *Determine the effects of a Beach Habitat Building Flood on rainbow trout dispersal and population indices.*

In response to concerns about deteriorating beaches in Grand Canyon, the Bureau of Reclamation conducted a High Flow Experiment (HFE), designed to move sand from the thalweg and deposit it on the shores. Analyses indicated no significant dispersal of rainbow trout downstream of Lees Ferry during this experiment. However, the experiment appeared to cause declines in overall fish relative condition. This is likely a result of increased metabolism and/or subsequent scour of the aquatic foodbase during the experiment. Concerns about a potential loss of the 2008 cohort due to food limitations were alleviated since relative condition returned to levels observed in previous years during summer and fall sampling. Aquatic foodbase analysis pre- and post-HFE suggested New Zealand mudsnails (*Potamopyrgus antipodarum*) were negatively impacted by the experiment, which may have led to increased food availability, especially for young fish, immediately following the experiment. Flexibility in management objectives is needed to allow for maintenance of fish densities that will increase relative condition, growth and PSD over a range of flow regimes. Modifying flow regimes to limit rainbow trout recruitment should be evaluated as a means of making progress toward size structure, growth and condition objectives.

High overall densities, low size structure and decreased relative condition indices support the conclusion that the system may return to a state of strong density-dependence. Water and foodbase quality will be essential to ensure the persistence of the Lees Ferry trout populations. Dam management should seek to establish favorable conditions for attaining population size structure (i.e., PSD) and relative condition (K_n) objectives.

INTRODUCTION

The Arizona Game and Fish Department has been monitoring and performing research on trout in Glen Canyon since the mid 1960's. Rainbow trout (*Oncorhynchus mykiss;* RBT) were initially stocked in the Colorado River below Glen Canyon Dam (GCD) in 1964 and since that time, fish management efforts, dam operations, and flow regimes have interacted to influence the trout community (Arizona Game and Fish Department [AGFD] 1996; Persons et al. 1985; Marzolf 1991; Reger et al. 1995; McKinney and Persons 1999; McKinney et al. 1999 a, c, d). Impacts of regulated flow on rainbow trout in the Lees Ferry tailwater has been a source of interest for resource managers and the public for several decades (Persons et al. 1985; Maddux et al. 1987; Reger et al. 1995, McKinney and Persons 1999, McKinney et al. 1999 a, d; McKinney et al. 2001 a; McKinney and Speas 2001). Understanding fish ecology in relation to dam operations is essential in order to integrate water, power, and fishery management goals.

Ecology of non-native rainbow trout in the Lees Ferry tailwater (river mile [RM] -15 to RM 0; Figure 1) is strongly influenced by operations of Glen Canyon Dam (McKinney and Persons 1999, McKinney and Speas 2001; McKinney et al. 1999 b, c; McKinney et al. 2001 a, b). Rainbow trout in the tailwater provide a popular recreational fishery and coexist with native flannelmouth sucker (*Catostomus latipinnis*; FMS) and non-native common carp (*Cyprinus carpio*; CRP). From 1991 through 1997, higher mean and less variable releases from GCD favored high standing stocks of rainbow trout, but size-related changes occurred in relative condition and bioenergetics of fish (McKinney et al. 1999a; McKinney and Speas 2001). Small fish (< 305 mm) were strongly affected by low and variable releases from the dam, but not by biotic variables which allowed them to meet maintenance energy requirements. In contrast, large fish (≥ 305 mm) were not affected by flow variability but were strongly influenced by biotic factors (i.e. density-dependence) associated with degradation of the aquatic foodbase. Large fish rarely met maintenance energy requirements (McKinney and Speas 2001). Relative condition of large fish peaked in 1994 and then fell 10 % by 1997, whereas condition of small fish was generally stable between 1991 and 1997. From 1997 to 2000, Speas et al. (2004b) noted a marked reduction in year-to-year variance in catch-per-unit-effort (CPUE), relative condition (K_n) and proportional stock density (PSD; Speas et al. 2004b), likely caused by the impacts of increased densities on the foodbase in the mid 1990's.

Standardized monitoring of the trout fishery using electrofishing (EF; Sharber et al. 1994) at fixed sampling locations was initiated in 1991 and has provided data on response of the RBT population to dam operations (McKinney and Persons 1999; McKinney et al. 1999a, c, d; McKinney et al. 2001a). In recent years, the Grand Canyon Monitoring and Research Center (GCMRC) sponsored a series of protocol evaluation panels for external scientific review of Colorado River sampling protocols (http://www.gcmrc.gov/pep/troutPEP.htm). This scientific review panel recommended increasing the overall sample size through reduction in length of existing fixed transects and addition of randomly selected sites. Random components of this augmented, serially alternating sampling design (Urquhart et al. 1998) are intended to give representative estimates of fishery status, whereas fixed components ensure continuity with existing trend data. Increasing the number of sample transects per sampling occasion also provides increased statistical power to detect changes in fishery variables on a yearly time scale (Speas et al. 2004c).

In this report, we present results from fish monitoring activities in the Lees Ferry tailwater during 2008. Herein we will compare and contrast data collected in fixed and random sites from 2008, and evaluate the serially alternating sampling design. Our monitoring objectives have not changed since 2002 and include evaluating the status and trends in relative abundance (CPUE), population structure (size composition and PSD), growth rate, and relative condition (K_n) of rainbow trout. We will also present observed changes in relative abundance, relative condition, and size structure, if any, following a High Flow Event (HFE) that occurred in March 2008. This high flow event was designed to allocate sand from the river to the shorelines to improve existing beaches along the river.

METHODS

Field Collections

We collected electrofishing (EF) samples in the Lees Ferry tailwater (Figure 1) four times during 2008 (exact dates for specific trips are provided in Table 2). For all sample occasions we used two 16' Achilles inflatable boats outfitted for electrofishing, applying pulsed DC (~310 V, ~15 A; Sharber et al. 1994) to a 35-cm spherical electrode system. Sampling commenced shortly after dusk and persisted 5-7 hours per night.

During each monitoring survey, we electrofished 9 fixed and 27 random sites covering approximately 4 km of shoreline area (see Speas et al. 2004b). The 27 random transects were selected without replacement from strata containing the remaining sample units found in river kilometer (RK) 0.9 – 26.85. We stratified sample units in two ways: 1) by shoreline type / relative abundance combinations and 2) longitudinally. The shoreline type stratification was comprised of talus/cobble bar shorelines, which are characterized by the highest CPUE values observed in 2001 (ca. 5.3 fish/min. EF; Speas et al. 2004b) and sand bar/cliff face shorelines characterized by the lowest CPUE values from 2001 (ca. 3.6 fish/min EF; Speas et al. 2004b). We selected specific shoreline types according to their availability (percentage of shoreline length) within river subreaches. The longitudinal stratification is by river mile, upper (RK 0.9 – 8.15), middle (RK 8.15 - 19.05) and lower (RK 19.05 – 26.85) subreaches of the tailwater below GCD. Longitudinal stratification also allowed randomization while maintaining safety and logistical integrity (i.e., boats visit the same section of the river on each night) as well as among longitudinal gradients in fish density (Speas et al. 2004b).

We measured total length (TL; mm) for all fish captured and weight (g) for most fish when conditions permitted accurate weight measurments.. We sexed fish based on manual extrusion of gametes. At fixed transects, we implanted untagged RBT > 150 mm TL with 400 kHz passive integrated transponder (PIT) tags and clipped adipose fins of all salmonids receiving PIT tags to monitor tag loss. Untagged native species (i.e. FMS) > 150 mm TL were also implanted with 134.2 kHz PIT tags. This marking program is primarily intended to provide information on fish growth. We injected all PIT tags (400 Khz and 134.2 kHz) ventrally into the fish body cavity with the insertion point immediately posterior to the pelvic fin. In 2007, we began inserting individually numbered Floy tags into rainbow trout > 200 mm TL that were captured in our random transects. Tags were inserted through the dorsal pterygiophores near the dorsal fin insertion. This tagging regime was initiated to produce open population estimates in the near future.

A subsample of RBT were sacrificed in the Lees Ferry tailwater in 2008 for age and diet analysis (AGFD), disease determination (Washington Animal Disease Diagnostic Laboratory, Washington State University, Pullman, WA; WADDL), and parasitological evaluations (USGS Biological Resources Division, Madison, WI; BRD). For the age and diet analysis, we sacrificed 5 RBT from each fixed site during each sampling trip varying in size from smallest to largest, removed their stomachs, and extracted sagittal otoliths. We also sacrificed 63 RBT in 2008, removed and froze their heads, and shipped them to WADDL to test for whirling disease. Additionally, 21 whole, live RBT specimens were collected and processed by Dr. Rebecca Cole for parasitological evaluations (Cole 2002). Unless sacrificed for BRD, whirling disease, or diet and age analysis, all fish were released alive near the location of capture.

Data Analysis

Evaluation of data from fixed and random sites

The role of fixed sites is primarily to provide long-term trend data to monitoring programs while data from random sites are the best point estimates of fishery status (Urquhart et al. 1998.) However, guidelines for statistical analyses of such data appear ambiguous as to whether the two types of data can be combined for more powerful (i.e. larger sample size) evaluation of long-term trends (S. Urquhart, *personal communication*). To evaluate differences in means and variances of the two types of data, we compared size-stratified data (CPUE, K_n) and size structure (PSD) from fixed and random sites in 2008 using one-way analysis of variance (ANOVA; S. Urquhart, *personal communication*). We then used Levene's test of homogeneity of variance on site type (fixed vs. random) to test the null hypothesis that error variance in fixed and random sites are equal. If significant differences were not apparent, fixed and random site data were pooled to increase power for long-term trend detection (Makinster et al. 2007). All statistical tests were considered significant at the $\alpha = 0.05$ level.

Long term monitoring

We computed CPUE as fish captured per minute of EF, and indexed size structure of the catch by calculating PSD (Anderson and Nuemann 1996; McKinney et al. 1999a) as the ratio of "quality" sized fish to the sum of "quality" and "stock" sized fish, or

$$(\# \text{ fish} \geq 406 \text{ mm TL} / \# \text{ fish} \geq 305 \text{ mm TL})*100$$

Fish ≥ 406 mm have been protected from harvest by AGFD fishing regulations, and most fish ≥ 305 mm are sexually mature (McKinney et al. 1999a) and generally desired by Arizona anglers (Pringle 1994). We also computed CPUE for the following length categories: < 152 mm TL, 152-304 mm TL, 305-405 mm TL and > 405 mm TL.

We determined relative condition factor (K_n; Le Cren 1951) as

$$K_n = W / W' * 100$$

where W′ is the standard weight relationship $e^{[(-4.6 + 2.856*LN(TL))]}$ incorporating all Lees Ferry RBT length and weight data collected since 1991. We evaluated fishery data (CPUE, K_n, PSD) from fixed EF sites by inspection of confidence intervals and means calculated for each year and by simple linear regression where trends appeared evident.

Effects of the High Flow Experiment

We examined the impacts of the 60-hour, 2008 HFE on the traditional fishery indices (CPUE, K_n, and PSD). We used ANOVA to examine differences between before and after the flood event. Additional AVOVAs were used to determine if size-selective differences in CPUE and K_n were seen prior to and following the flood.

RESULTS

Discharges from Glen Canyon Dam were seasonally variable during 2008 (Figure 2). Flows during January 2008 ranged from about 9,500 to 16,500 cfs daily and were followed by low fluctuating flows in February ranging between about 8,750 to 13,300 cfs daily. Discharges for the HFE began on March 5 with an upramp ranging between 13,100 to 36,600 cfs. Daily average discharge for the HFE was maintained at about 41,800 cfs until March 8 when the HFE ended (see Figure 10). Normal ROD discharges occurred following the HFE until July. Summer flows (July-August) ranged from about 10,000 to 18,300 cfs daily. Steady flows began in September 2008 and lasted until November. This regime consisted of a constant discharge of about 12,300 cfs daily and was initiated in an attempt to raise mainstem Colorado River water temperatures around the confluence of the Little Colorado River to benefit the endangered humpback chub (*Gila cypha*). This experiment is proposed to last from 2008-2012 and results of the impacts on rainbow trout and humpback chub are ongoing.

Whirling disease analyses were negative for all samples collected during 2008 (Jim Thompson, AGFD Fish Health Laboratory, personal communication). Results of parasitological evaluations (USGS-BRD, Madison, WI), and AGFD diet analysis are incomplete at the time of submission of this report.

Evaluation of data from fixed and random sites

Analysis of size-stratified RBT data revealed no differences in CPUE, K_n, and PSD among fixed and random sites during 2008 (Table 1). Thus, data from both fixed and random sites were pooled to increase our ability to detect trends in Lees Ferry RBT population indices. Data collected in February 2008 (pre-HFE) were not included in this analysis.

Long-term monitoring

A total of 3,601 fish from 7 species were captured during long-term monitoring at Lees Ferry in 2008 (Table 2). Rainbow trout were the most prevalent species captured (99%) followed by common carp (0.4%), flannelmouth sucker (0.2%), brown trout (BNT; *Salmo trutta*; 0.1%), walleye (WAL; *Sander vitreus*; 0.06%), green sunfish (*Lepomis cyanellus*; 0.03%), and bluehead sucker (BHS; *Catostomus discobolus*; 0.03%). The captured bluehead sucker represents the first occurrence of this species in the Lees Ferry tailwater during AGFD monitoring efforts dating from 1991. A total of 215 RBT were implanted with PIT tags and 8 PIT tagged fish were recaptured during 2008 sampling. A total of 432 RBT were implanted with Floy tags and 7 Floy tagged fish were recaptured. A total of 4 FMS were implanted with 134.2 kHz PIT tags and 3 fish were recaptured. A total of 12 CRP were Floy tagged with no recaptures. A total of 3 BNT were PIT tagged and 1 fish was recaptured (see Table 3 for detailed mark and recapture information). The mean total length of RBT captured during 2008 was 138 ± 2.94 mm, (mean ± 2 S.E.).

Length frequency analysis showed a typical bimodal RBT distribution during March and July sampling with the majority of fish comprising total lengths < 150 mm and > 350 mm (Figure 3). However, roughly 76% of RBT captured during our October sampling were < 150 mm TL, indicating a strong spawning event occurred in the early spring and survival through the summer and fall were relatively high. Relatively few adult-sized fish (i.e. > 225 mm TL) were captured during October, likely due to netter saturation of small fish (Figure 3).

Overall, the CPUE of RBT at Lees Ferry in 2008 increased significantly from 2007. Rainbow trout CPUE for all sampling and sizes during 2008 was 3.50 ± 0.78 fish per minute of electrofishing (mean ± 2 S.E.), which is similar to the densities of RBT in the early 2000's (Figure 4). This overall increase in relative abundance density is largely attributable to the dramatic increase in numbers of RBT < 152 mm TL since 2007 (Figure 5, panel A). Relative abundance of RBT in the 152 to 304 mm TL size class has decreased since 2002 and is similar to those observed in the early 1990's (Figure 5, panel B). Relative abundance of RBT in the 305 to 405 mm TL size class has also declined since 2002 and is similar to those observed in the mid-1990's (Figure 5, panel C). Relative abundance of RBT > 406 mm TL in 2008 was similar to the low levels observed since 2000 (Figure 5, panel D).

A total of 1142 anglers were contacted during 375 interviews conducted near the Lees Ferry boat ramp (AGFD Region 2, unpublished data). Angler CPUE from creel surveys closely resemble the trends seen in the electrofishing CPUE data for 305-405 mm TL RBT since 1991 (Figure 6). Angler catch rates declined substantially in 2002 and the trend has remained relatively stable since. Lees Ferry anglers averaged about 0.66 ± 0.05 fish per hour during 2008 (mean ± 2 S.E.).

As indicated by the declining trend in abundance of RBT greater than 305 mm TL since 2003, PSD remained low in 2008 (Figure 7). The PSD in recent years (2001-2005) has remained relatively stable but is significantly lower than that observed in 2000. Proportional stock density during the period of this study was 5.43 ± 3.20 (mean ± 2 S.E.). However, we observed an increasing trend in rainbow trout PSD since 2006 (Figure 7).

Rainbow trout K_n for all sizes of fish was significantly lower in 2008 than in 2007 (Figure 8). Mean K_n in 2008 was 80.25 ± 0.79 and was similar to trout condition in 1998. Size-stratified analysis of K_n showed decreases in rainbow trout condition during 2008 compared to 2007 for all size classes except for fish < 152 mm TL (Figure 9). Relative condition for rainbow trout < 152 mm TL in 2008 was similar to condition observed in 2007.

Effects of the High Flow Event

The HFE occurred in March 2008, and consisted of discharges around 42,000 cfs that lasted for a period of about 3 days (Figure 10). Rainbow trout were the most abundant species captured during February (i.e. pre-HFE sampling) and March (i.e. post-HFE sampling) followed by BNT and CRP (see Table 2 for post-HFE sampling catch and Table 4 for pre-HFE sampling catch). Rainbow trout CPUE of all size classes combined before and after the HFE was not statistically significant (1.40 ± 0.44 and 1.34 ± 0.51 fish per minute, respectively; Figure 11, panel A). Rainbow trout PSD was also not significantly different prior to and following the HFE (Figure 11, panel B; see also Table 5). However, significant differences were observed in K_n for all size classes combined prior to and following the HFE (Figure 11, panel C). Mean K_n during pre- and post-HFE was 82.15 ± 1.44 and 77.30 ± 1.23, respectively ($P < 0.0001$; mean ± 2 S.E.). Size-stratified analysis of CPUE indicated no differences among size classes during pre- and post-HFE sampling (Figure 12; see Table 5). Significant differences were observed however in K_n for the < 152 mm TL and 305-405 mm TL size classes (Figure 13, see Table 5).

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DISCUSSION

The GCMRC-sponsored protocol evaluation panel suggested increasing overall sample size in the Lees Ferry tailwater by reducing the length of fixed electrofishing transects and incorporating randomly selected transects. We initiated this augmented, serially alternating sampling regime (Urquhart et al. 1998) in June 2002. Fixed transects served to ensure comparison with historical data and random transects provided representative estimates of fishery status. Our analysis of long-term fixed and random transects over similar temporal scales in 2008 showed no differences in size-stratified estimates of relative abundance, relative condition, and size structure. Thus, we pooled data from both fixed and random transects to increase our ability to detect rainbow trout population trends over time (Speas et al. 2004c). While our analysis of this data consisted of relatively simple statistics (ANOVA; S. Urquhart, *personal communication*), we recognize the potential for more robust statistical analysis of this data. We hope additional input from future protocol evaluation panels will help with this issue.

Overall catch rates of rainbow trout at Lees Ferry substantially increased in 2008 compared to 2007. This increase is likely due to our high catch of young fish in 2008, particularly during October. Considering that young-of-the-year rainbow trout become vulnerable to electrofishing during the fall, it is likely a strong spring spawn and/or increased survival occurred during 2008. Redd counts at Lees Ferry have increased by orders of magnitude since 2005 (J. Korman, *personal communication*), suggesting conditions that limited larval rainbow trout production in recent years have been alleviated. The relatively low densities of rainbow trout since 2005 may have relieved food and space limitations that once constrained the fishery. Also, the high relative condition observed in 2007 suggests mature rainbow trout were able to meet maintenance energy requirements needed to spawn (McKinney and Speas 2001).

The 2008 rainbow trout cohort is one that is likely unprecedented during our monitoring efforts that have occurred since 1991. Since young-of-the-year fish dominated our catch during the October sample, it appears these fish successfully survived any compensatory survival mechanisms that typically occur annually during August-September (J. Korman, C. Walters, and L. Coggins, *personal communication*). It is likely, however, our capture probabilities of rainbow trout increased in October with a stable flow regime. Nevertheless, previous research on the Lees Ferry rainbow trout population has shown the persistence of a cohort over time that was produced during a year with stable flows (Speas et al. 2004a). Further sampling in 2009 and later will determine if this is true for the coincident cohort.

The High Flow Event that occurred in 2008 did not lead to substantial effects on the rainbow trout population at Lees Ferry, which is similar to the findings of studies regarding previous experimental flows (AGFD 1996; Makinster et al. 2007). Our ability to detect significant differences prior to and following the event were strengthened by sampling the exact same sites before and after the event. Relative abundance of all size classes of fish were similar during pre- and post-HFE sampling. This suggests this relatively high flow event did not cause substantial downstream displacement of any sized fish from Lees Ferry. Similarly, the size structure of the rainbow trout population did not differ between pre- and post-HFE sampling. The size structure remains relatively low compared to the early 1990's but has shown an increasing trend since 2006. We did observe a decrease in relative condition in the overall rainbow trout population following the HFE. Further examination of individual size classes revealed fish less than 152 mm and fish 305 to 405 mm were most affected. We attribute the decrease in relative condition to increased metabolism and differential food availability that likely occurred during the experiment. Previous research suggests energy allocations to normal activities (i.e. feeding) may be reduced by about one quarter in response to a physical stressor (Barton and Schreck 1987). We believe this decrease in relative condition following the experiment represented a minimal, temporary impact to the overall rainbow trout population considering relative condition returned to similar levels observed in previous years.

The High Flow Event did appear to reset the aquatic foodbase. Observations made during and after the experiment indicated significant scour of senescent food resources occurred and were displaced downstream. Subsequent monitoring of the foodbase following the experiment suggested increased diatom production and decreased abundance of New Zealand mudsnails (*Potamopyrgus antipodarum*, NZMS; T. Kennedy and E. J. Rosi-Marshall, *personal communication*). The decline in NZMS likely made food resources available to other secondary consumers (i.e. amphipods, chironomids, gastropods) since NZMS have been known to restructure food webs in other systems (Hall et al. 2006). However, the data needed to support this observation are unavailable at this time. The decreased abundance of NZMS was likely a temporary result of the experiment since NZMS abundances appeared to rebound by late summer.

Current conditions of the fishery suggest the rainbow trout population may return to a state similar to previous years (i.e. 1997-2000) where density-dependent constraints limited food and space availability (Speas et al. 2004a, b). The relative abundance of young rainbow trout currently is similar to observed levels in the late-1990's and early-2000's. Similarly, relative condition in 2008 resembles condition observed in 1998 when fish were likely too energetically compromised to produce sufficient somatic or gonadic growth (McKinney and Speas 2001). The prevalence of the 2008 cohort is likely driving the observed trends in relative abundance but not relative condition because these fish typically have the highest relative condition amongst all size classes.

Our data suggests the reset of the aquatic foodbase as a result of the HFE coupled with the stable flow regime that occurred during September and October created optimal conditions for the survival of young rainbow trout. Previous years when food and space availability were likely limited (i.e. 1997-2000) suggested juvenile rainbow trout experienced high compensatory survival (J. Korman, *personal communication*), particularly during late-summer, early-fall months. The timing of the 2008 stable flow regime appeared to negate any of these mechanisms that may have worked to control fry survival. Future sampling over the next few years will determine if this new cohort persists within the Lees Ferry tailwater; similarly to the cohort that experienced a similar stable flow regime during the summer of 2000 (Speas et al. 2004a). The size structure of the fishery currently is similar to the lowest observed on record but has shown an increasing trend since 2006. Creel results confirm the changes seen in the electrofishing trends. Angler catch rates have shown an increasing trend since 2006. If the 2008 cohort persists as expected, we expect angler catch rates to increase in the near future.

ACKNOWLEDGEMENTS

Grand Canyon Monitoring and Research Center provided funding for the present studies. We wish to thank GCMRC personnel Stuart Reider, Steve Jones, Peter Weiss, Scott Perry, and Brett Starks for all their hard work driving boats in the field and keeping clean, legible data. We also thank Carol Fritzinger for coordinating trip schedules and equipment. Numerous Game and Fish personnel volunteered their time to collect this data, and to them our thanks are due.

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Table 1. Results of analysis of variance on rainbow trout (RBT) relative abundance (CPUE; catch per minute), relative condition (K_n), and size structure (PSD; proportional stock density) by size class between fixed and random transects in the Lees Ferry tailwater fishery. Data represent similar time frames for each transect type (March, July, and October, 2008). Data collected prior to the High Flow Experiment (March 6-8, 2008) were excluded from this analysis.

	RBT Size class (mm)			
Parameter	**< 152 mm**	**152 – 304 mm**	**305 – 405 mm**	**> 405 mm**
Abundance				
Mean CPUE (±2 S.E.)				
Fixed	2.80 (1.51)	0.29 (0.21)	0.52 (0.20)	0.05 (0.05)
Random	2.69 (0.86)	0.28 (0.06)	0.44 (0.11)	0.04 (0.03)
F	0.01	0.01	0.50	0.08
DF	1, 104	1, 104	1, 104	1, 104
***P*-value**	0.91	0.93	0.48	0.77
Condition				
Mean K_n (±2 S.E.)				
Fixed	80.42 (2.51)	85.34 (2.61)	75.01 (1.72)	75.18 (6.57)
Random	83.25 (1.48)	84.26 (1.45)	76.33 (1.22)	73.85 (5.22)
F	3.64	0.50	1.51	0.10
DF	1, 202	1, 221	1, 384	1, 29
***P*-value**	0.06	0.45	0.22	0.76

	Entire fishery
Size structure	
Mean PSD (±2 S.E.)	
Fixed	4.99 (5.54)
Random	6.00 (3.28)
F	0.09
DF	1, 83
***P*-value**	0.76

Table 2. Number of each species captured per sampling trip by transect type in the Lees Ferry tailwater during 2008. Species are coded as followed: rainbow trout (*Oncorhynchus mykiss*; RBT); walleye (*Sander vitreus*; WAL); brown trout (*Salmo trutta*; BNT); common carp (*Cyprinus carpio*; CRP); flannelmouth sucker (*Catostomus latipinnis*; FMS); green sunfish (*Lepomis cyanellus*; GSF), and bluehead sucker (*Catostomus discobolus*; BHS). Data collected during February 2008 (pre-High Flow Event) are omitted from this analysis.

Trip ID	Transect type	Total catch						
		RBT	WAL	BNT	CRP	FMS	GSF	BHS
LF20080318	Fixed	91						
03/18-03/20/2008	Random	261						
	Total	***352***						
LF20080714	Fixed	141		2		1		
07/14-07/16/2008	Random	322	1					
	Total	***463***	***1***	***2***		***1***		
LF20081028	Fixed	830	1		1			
10/28-10/30/2008	Random	1927		2	13	6	1	1
	Total	***2757***	***1***	***2***	***14***	***6***	***1***	***1***
Grand total		**3572**	**2**	**4**	**14**	**7**	**1**	**1**
Percent of catch (%)		**99**	**0.06**	**0.1**	**0.4**	**0.2**	**0.03**	**0.03**

Table 3. Rainbow trout (*Oncorhynchus mykiss*; RBT), brown trout (*Salmo trutta*; BNT), and flannelmouth sucker (*Catostomus latipinnis*; FMS) growth information resulting from recaptures in 2008 of PIT tagged and Floy tagged fish in the Lees Ferry tailwater.

Tag type	Species	Tag number	Date marked	Mark location (RM)	Date recaptured	Recap location (RM)	Days out	Mark length (mm)	Recap length (mm)	Distance moved (miles)	Instant growth (mm/day)
PIT tag											
	RBT	436256230E	10/10/2006	-4.6	3/18/2008	-4.6	526	374	415	0	0.078
	RBT	436271265F	4/4/2006	-5.8	3/18/2008	-5.8	715	273	346	0	0.102
	RBT	434461045C	4/25/2007	-12	3/20/2008	-12	331	263	302	0	0.118
	RBT	4363565A0B	7/26/2007	-10.2	7/16/2008	-10.3	356	363	369	-0.1	0.017
	RBT	4364030024	7/14/2008	-4	10/28/2008	-4	107	367	379	0	0.112
	RBT	4365297B32	7/25/2007	-12	10/29/2008	-11.9	463	360	377	0.1	0.037
	BNT	3D9.1C2C9C8C5C	7/15/2008	-14.7	10/30/2008	-10.2	108	470	470	4.5	0.000
	FMS	3D9.1BF256371A	5/9/2007	59.1	10/30/2008	-9	541	471	487	-68.1	0.030
	FMS	3D9.1BF19F8F1B	4/5/2005	-12	10/30/2008	-9	1305	509	526	3	0.013
	FMS	3D9.1BF24E560F	3/13/2006	57.9	10/30/2008	-9	963	225	423	-66.9	0.206
Floy tag											
	RBT	AGFD 1188	7/26/2007	-6.5	3/1/2008	-6.3	219.8646	219	236	0.2	0.077
	RBT	AGFD 1089	4/24/2007	-2.5	2/28/2008	-2.5	310.875	333	359	0	0.084
	RBT	AGFD 0774	2/29/2008	-11.7	3/20/2008	-11.7	20.85556	316	322	0	0.288
	RBT	AGFD 0539	4/25/2007	-11.6	3/20/2008	-12	330.9007	410	403	-0.4	n/a
	RBT	AGFD 0139	7/25/2007	-11.8	3/20/2008	-12	239.9007	205	292	-0.2	0.36265005
	RBT	AGFD 0593	2/29/2008	-12.9	3/20/2008	-12.9	20.875	375	379	0	0.192
	RBT	AGFD 0698	7/26/2007	-4.1	10/28/2008	-4	461	320	339	0.1	0.041

Table 4. Number of each species captured during the February 2008 (pre-HFE) sampling trip by transect type in the Lees Ferry tailwater. Species are coded as followed: rainbow trout (*Oncorhynchus mykiss*; RBT); brown trout (*Salmo trutta*; BNT); and common carp (Cyprinus carpio; CRP).

Trip ID	Transect type	Total catch		
		RBT	**BNT**	**CRP**
LF20080228	Fixed	104	1	1
02/28-03/01/2008	Random	308	2	
Grand total		**412**	**3**	**1**
Percent of catch (%)		**99**	**0.7**	**0.2**

Table 5. Results of analysis of variance on rainbow trout (RBT) relative abundance (CPUE; catch per minute), relative condition (K_n), and size structure (PSD; proportional stock density) by size class between February and March 2008 (before and after a High Flow Experiment, respectively), in the Lees Ferry tailwater. Table includes data from both fixed and random transects. * denotes significance at the α = 0.05 level.

	RBT Size class (mm)			
Parameter	**< 152 mm**	**152 – 304 mm**	**305 – 405 mm**	**> 405 mm**
Abundance				
Mean CPUE (±2 S.E.)				
February	0.69 (0.30)	0.18 (0.09)	0.48 (0.19)	0.05 (0.04)
March	0.78 (0.38)	0.12 (0.08)	0.39 (0.16)	0.04 (0.04)
F	0.15	0.82	0.56	0.01
DF	1, 66	1, 66	1, 66	1, 66
***P*-value**	0.70	0.37	0.46	0.92
Relative condition				
Mean K_n (±2 S.E.)				
February	88.97 (4.56)	84.72 (3.68)	80.30 (1.61)	79.53 (4.60)
March	78.23 (2.31)	79.76 (3.43)	75.87 (1.58)	78.47 (5.51)
F	28.59	1.88	14.34	0.08
DF	1, 82	1, 69	1, 218	1, 22
***P*-value**	< 0.0001*	0.18	0.0002*	0.78
	Entire fishery			
Size structure				
Mean PSD (±2 S.E.)				
February	5.19 (4.16)			
March	5.72 (5.06)			
F	0.25			
DF	1, 47			
***P*-value**	0.88			

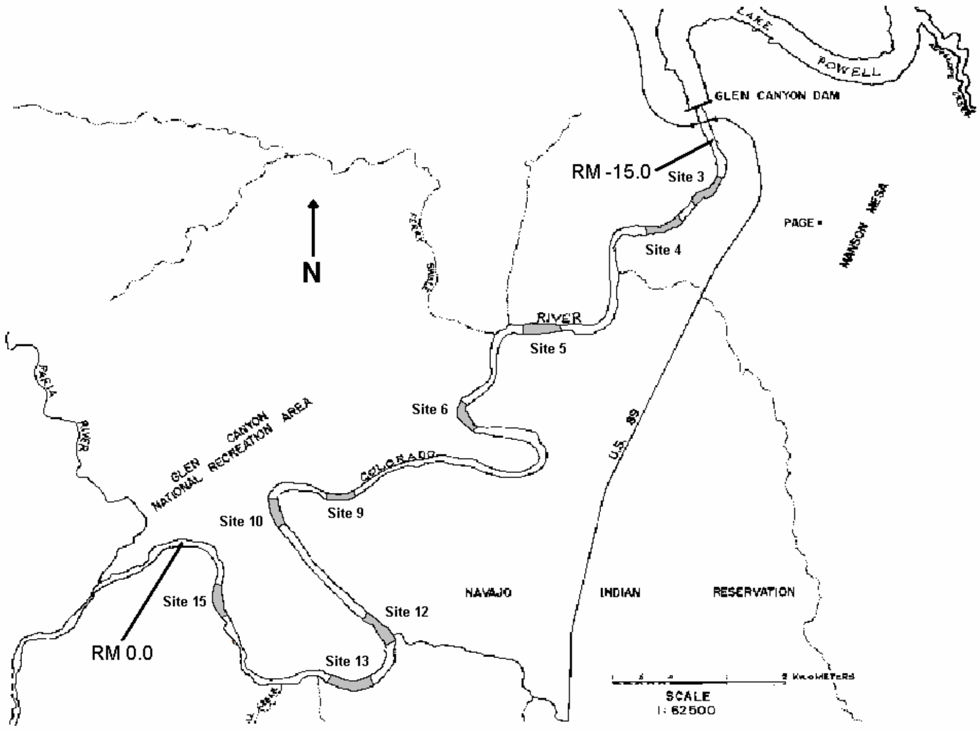

Figure 1. Map showing the Lees Ferry tailwater fishery below Glen Canyon Dam, on the Colorado River, Arizona. Fixed sampling locations are shaded gray.

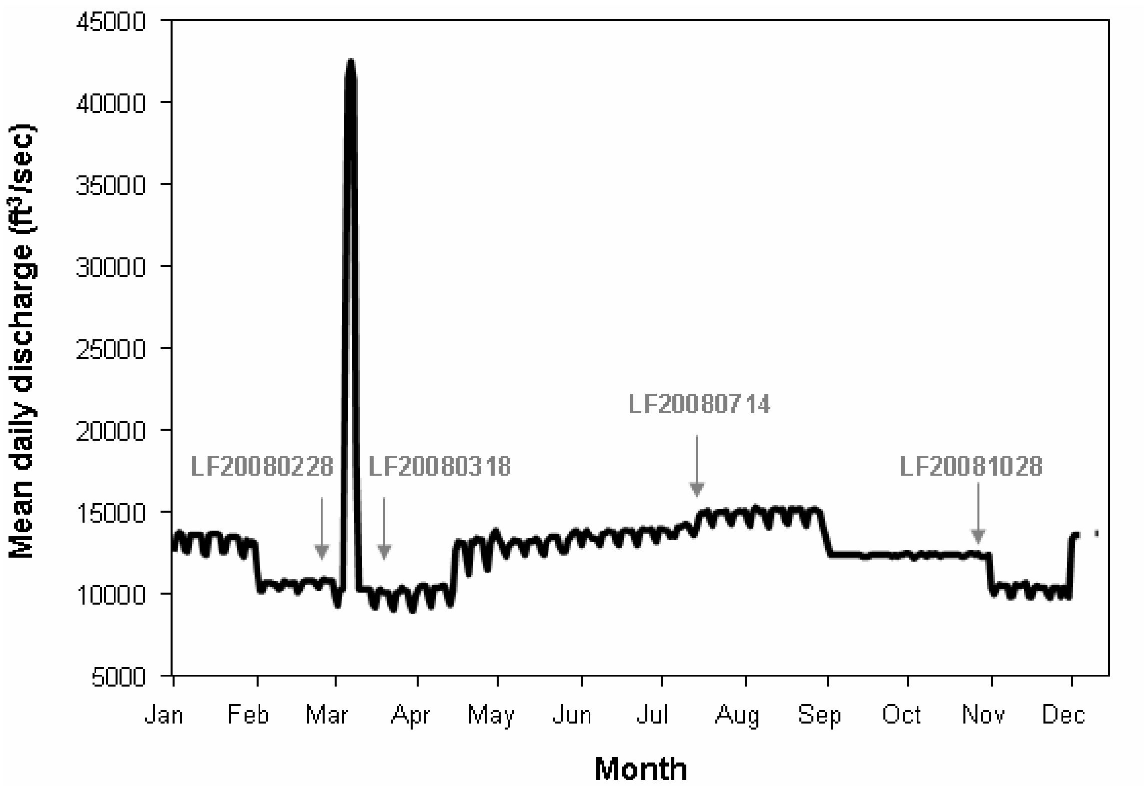

Figure 2. Mean daily discharge (cfs) from Glen Canyon Dam during 2008. Gray arrows and associated text depict AGFD sampling events.

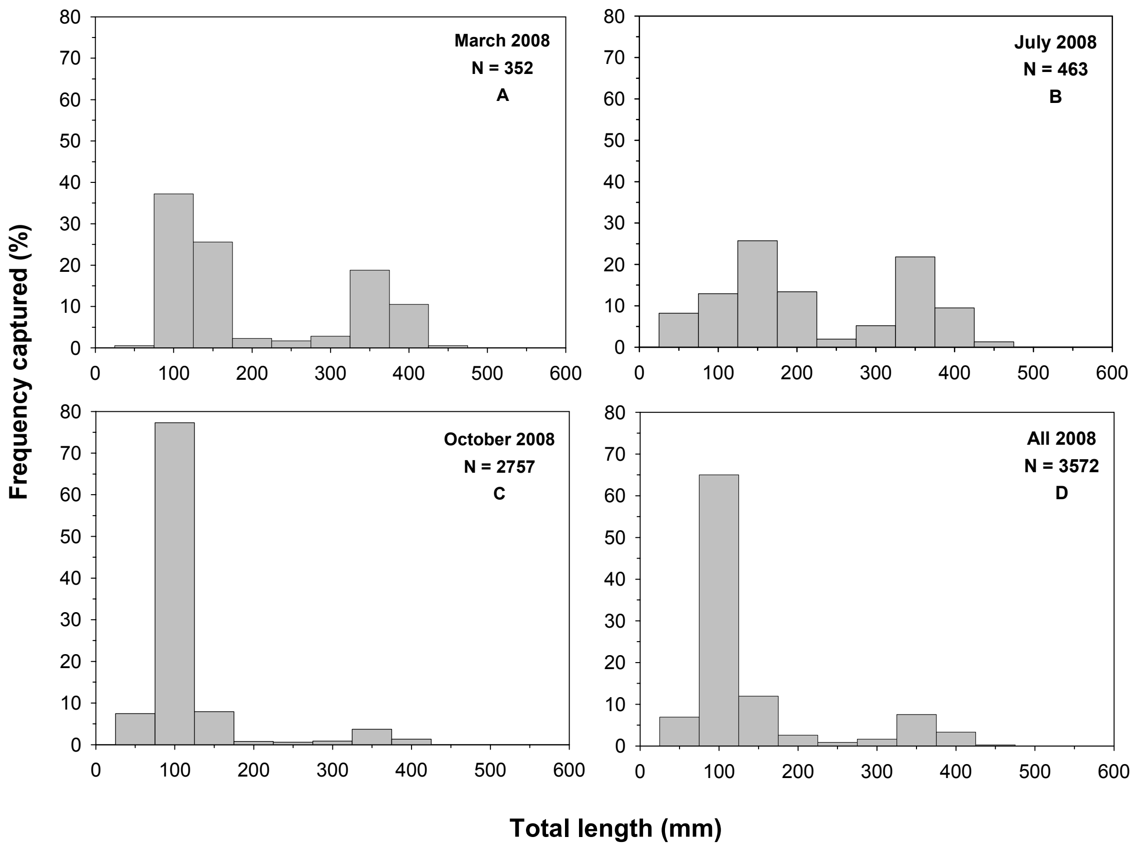

Figure 3. Lees Ferry rainbow trout length frequency distribution during March (panel A), July (panel B), October (panel C), and all sampling in 2008 (panel D). Data includes both fixed and random transects. Data from February 2008 (prior to a High Flow Experiment) was excluded from this analysis.

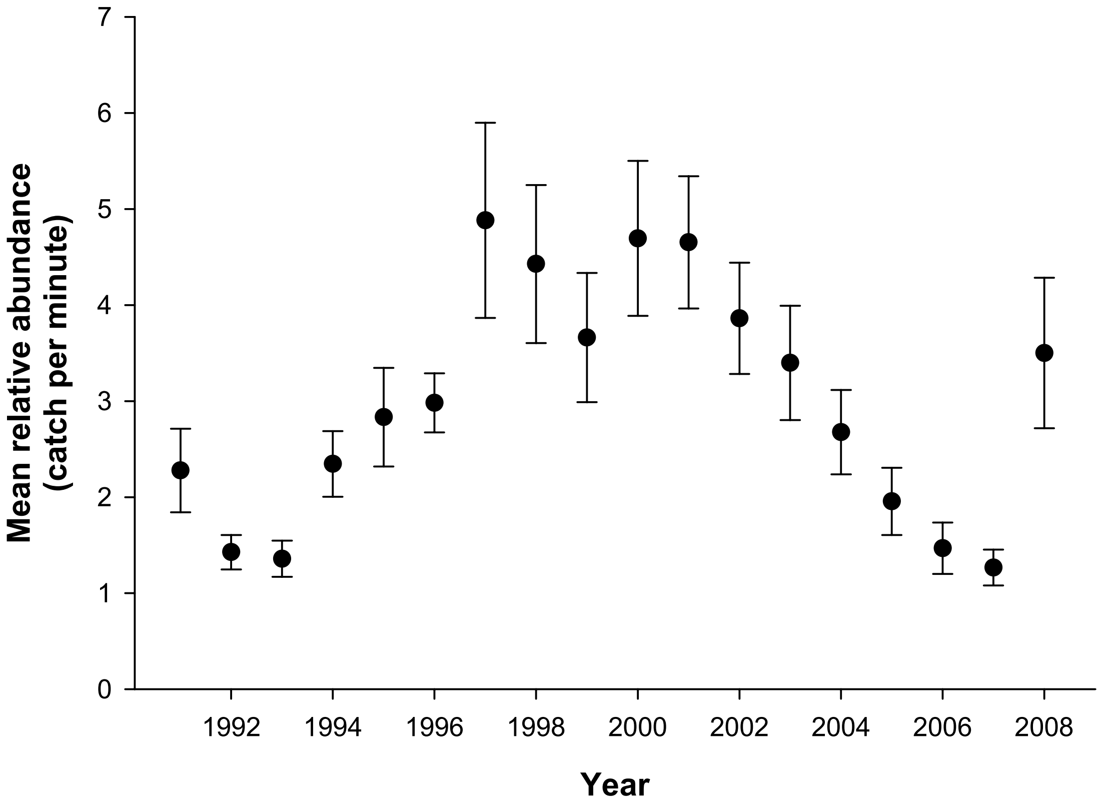

Figure 4. Rainbow trout mean relative abundance (catch per minute) in the Lees Ferry tailwater fishery, 1991-2008. Figure represents data from all size classes in both fixed and random transects. Data from February 2008 (prior to a High Flow Experiment) are excluded from this analysis. Bars represent ± 2 S.E. of the mean.

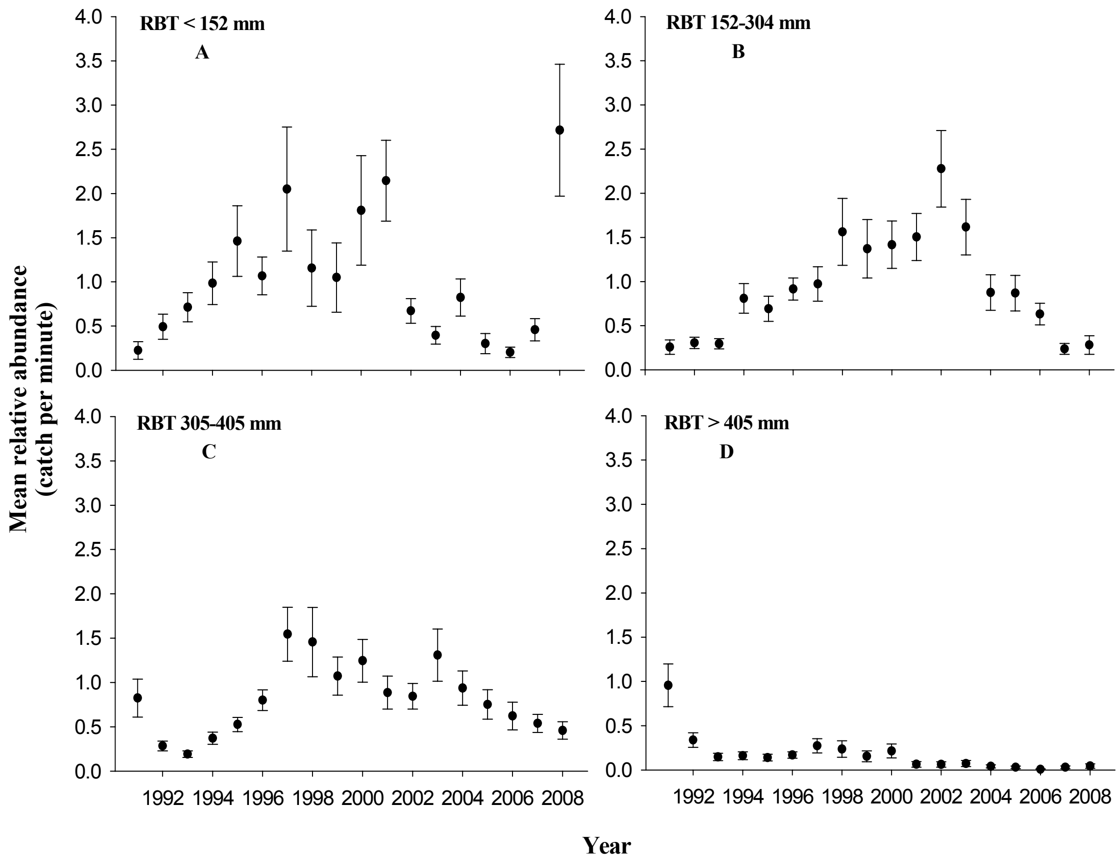

Figure 5. Rainbow trout mean relative abundance (catch per minute) for fish < 152 mm total length (TL; panel A), 152-304 mm TL (panel B), 305-405 mm TL (panel C), and > 405 mm TL (panel D) in the Lees Ferry tailwater fishery, 1991-2008. Figure represents data from both fixed and random transects. Data from February 2008 (prior to a High Flow Experiment) were excluded from this analysis. Bars represent ± 2 S.E. of the mean.

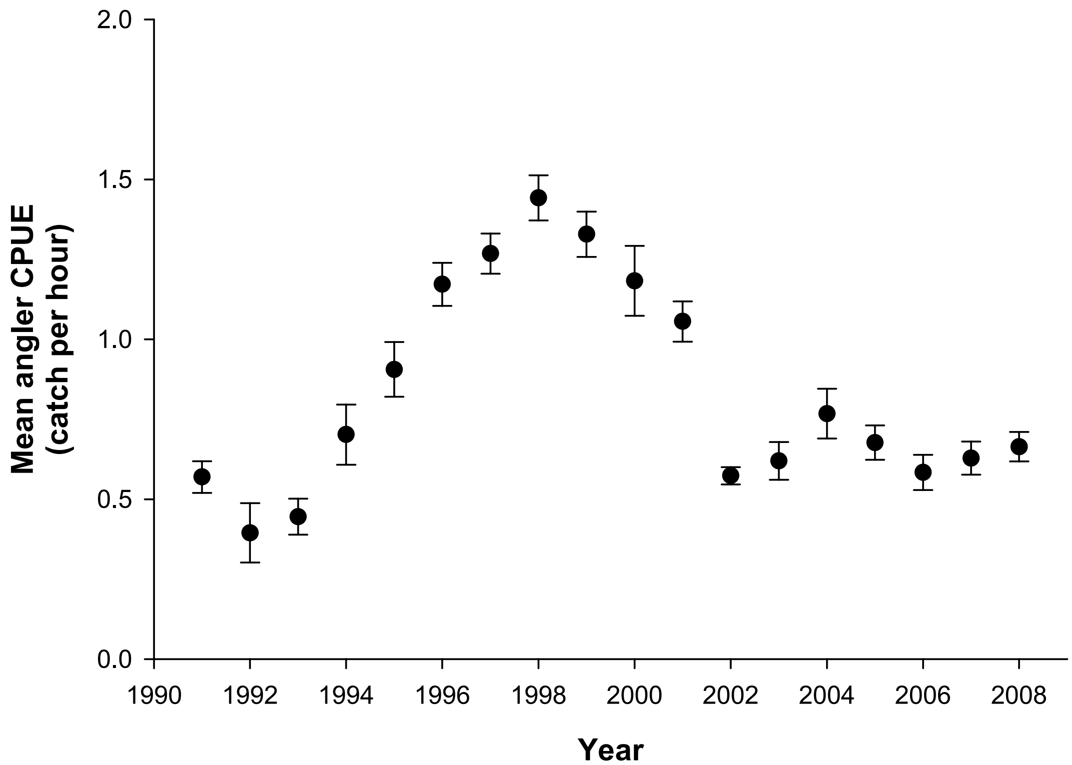

Figure 6. Mean angler catch-per-unit-effort (CPUE; catch per hour) of rainbow trout in the Lees Ferry tailwater fishery, 1991-2008. Bars represent ± 2 S.E. of the mean.

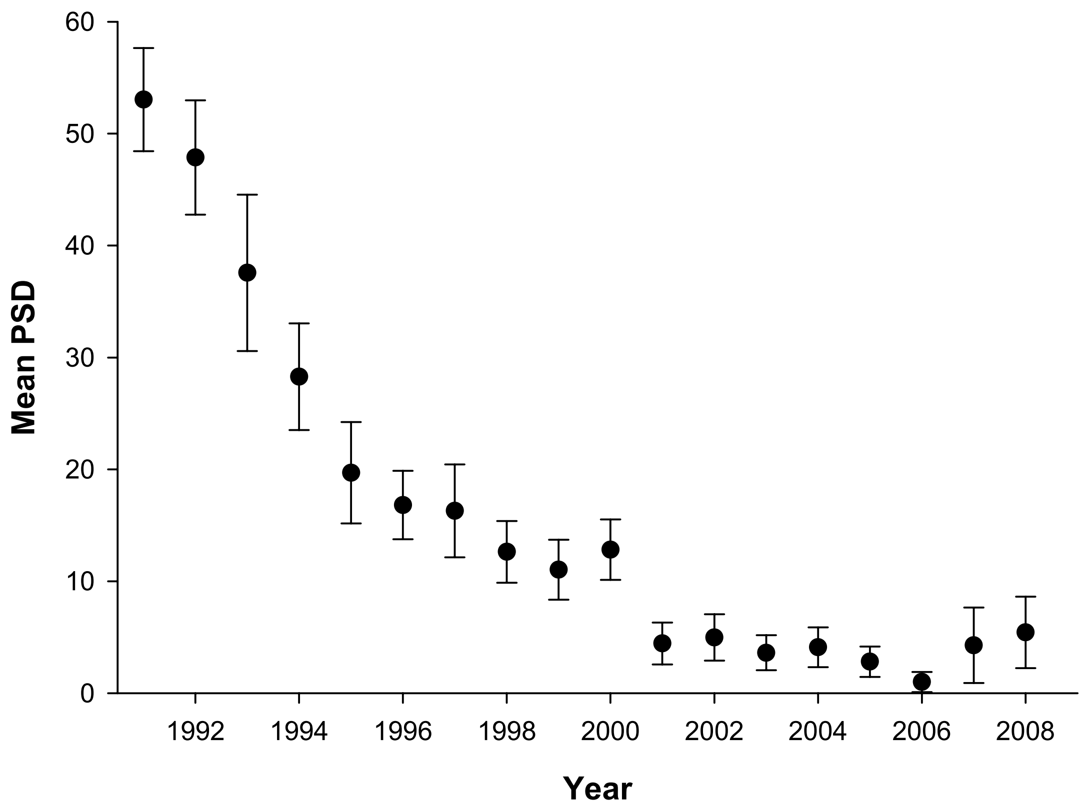

Figure 7. Rainbow trout mean proportional stock density ([# fish ≥ 406 mm TL / # fish ≥ 305 mm TL]*100; PSD) in the Lees Ferry tailwater fishery, 1991-2008. Figure represents data from both fixed and random transects. Data from February 2008 (prior to a High Flow Experiment) were excluded from this analysis. Bars represent ± 2 S.E. of the mean.

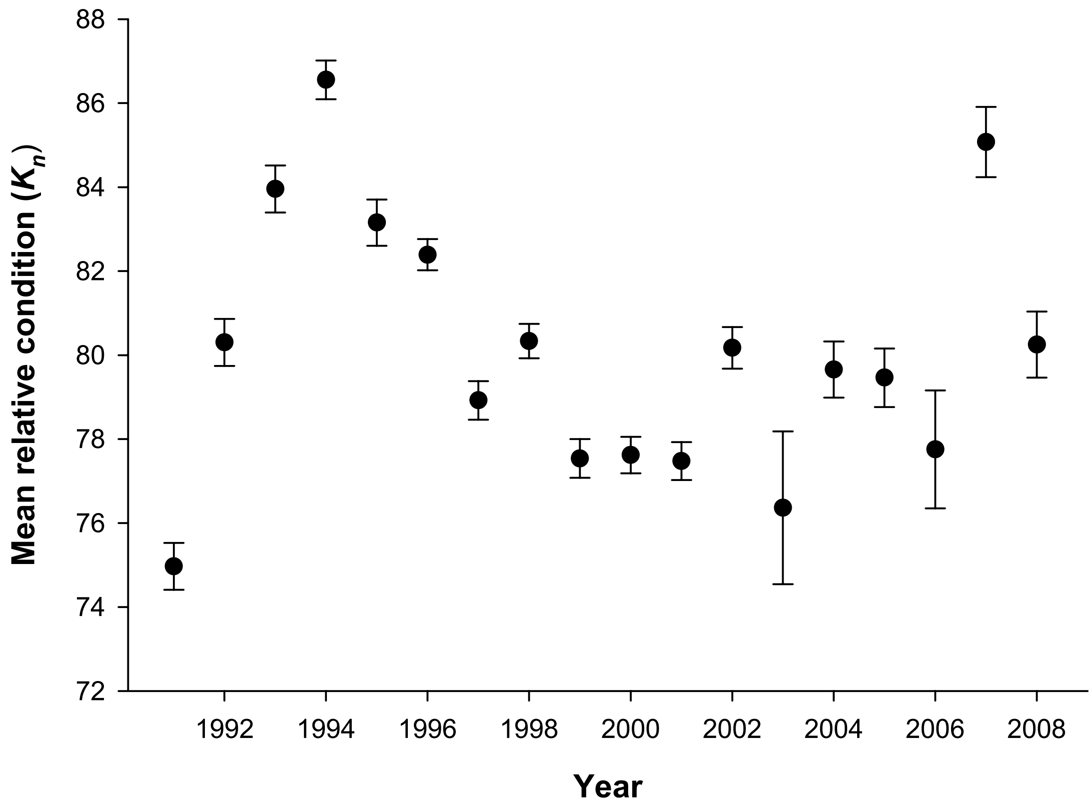

Figure 8. Rainbow trout mean relative condition (K_n) in the Lees Ferry tailwater fishery, 1991-2008. Figure represents data from all size classes in both fixed and random transects. Data from February 2008 (prior to a High Flow Experiment) were excluded from this analysis. Bars represent ± 2 S.E. of the mean.

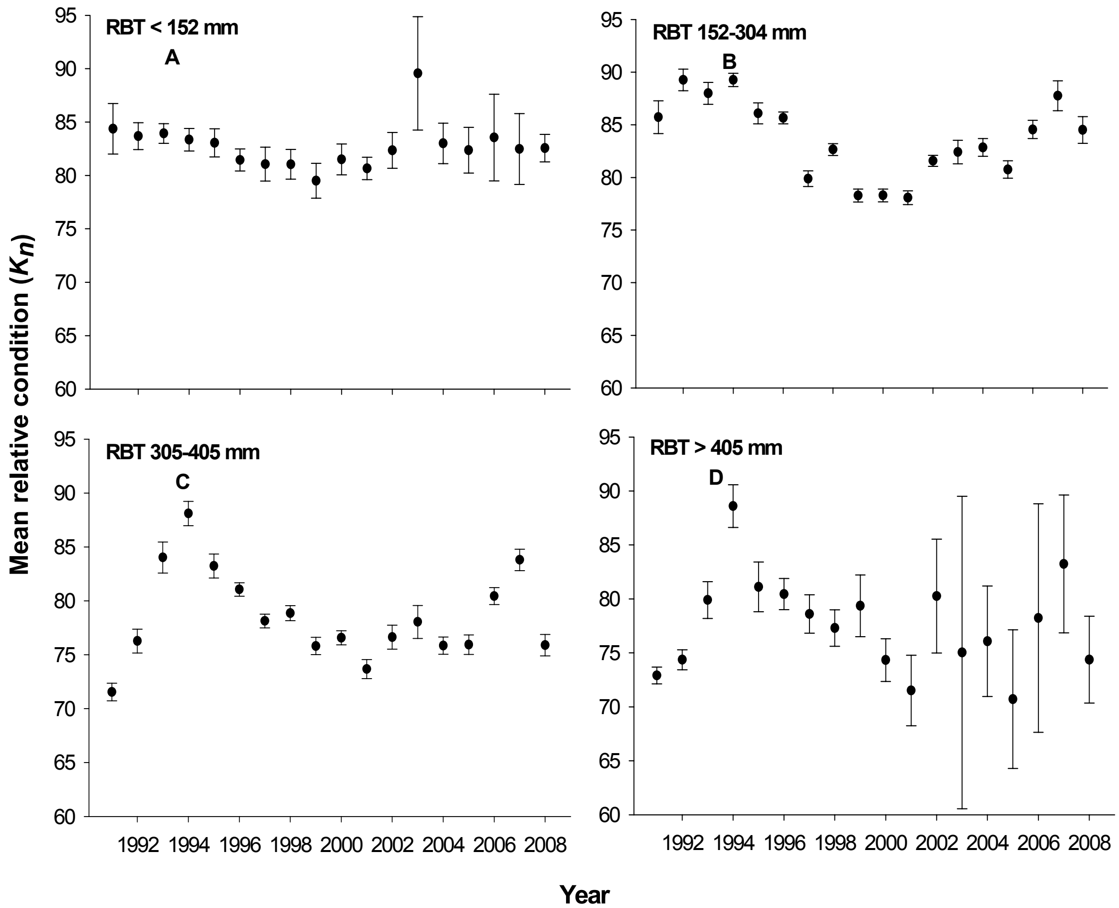

Figure 9. Rainbow trout mean relative condition (K_n) for fish < 152 mm total length (TL; panel A), 152-304 mm TL (panel B), 305-405 mm TL (panel C), and > 405 mm TL (panel D) in the Lees Ferry tailwater fishery, 1991-2008. Figure represents data from both fixed and random transects. Data from February 2008 (prior to a High Flow Experiment) were excluded from this analysis. Bars represent ± 2 S.E. of the mean.

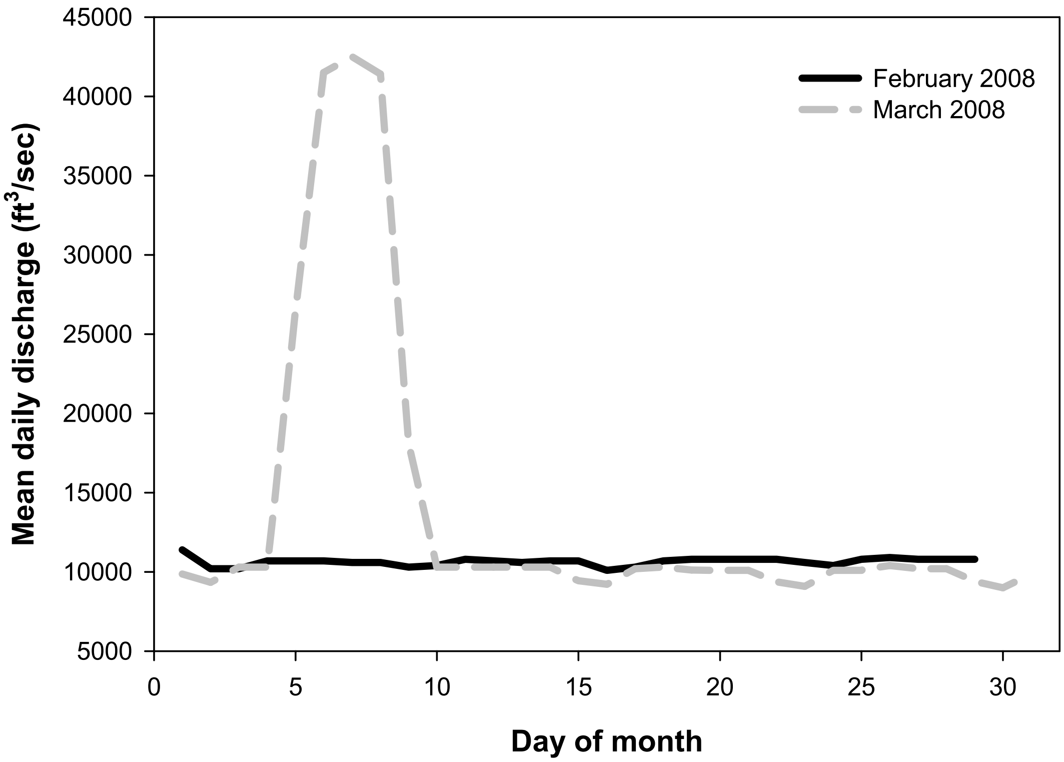

Figure 10. Mean daily discharge from Glen Canyon Dam during February 2008 (prior to a High Flow Experiment; black solid line) and March 2008 (during and after a High Flow Experiment; gray dashed line). Sampling the Lees Ferry tailwater occurred prior to the High Flow Experiment during 02/28-03/01/2008, and following the High Flow Experiment during 03/18-03/20/2008.

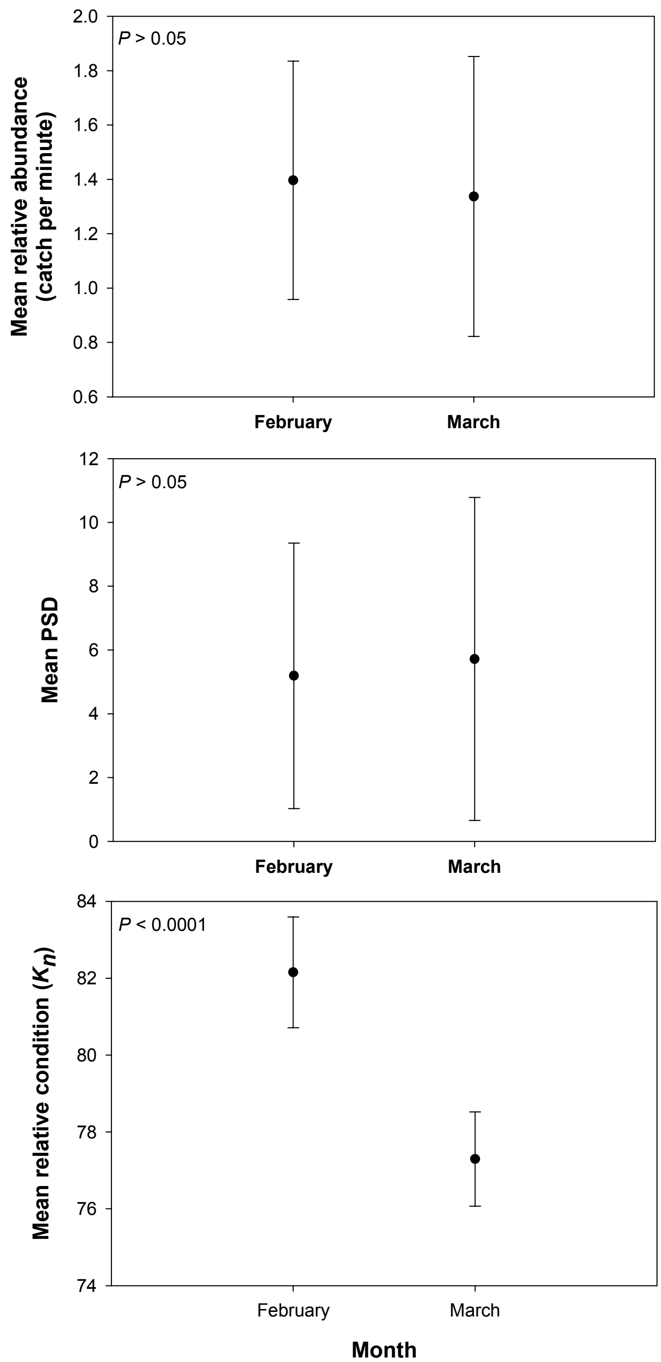

Figure 11. Mean rainbow trout relative abundance of all size classes (catch per minute; top panel), mean proportional stock density ([# fish ≥ 406 mm TL / # fish ≥ 405 mm TL]*100; middle panel) and mean relative condition of all size classes (K_n; bottom panel) before a High Flow Experiment (HFE; February) and after the HFE (March) in the Lees Ferry tailwater, 2008. Bars represent ± 2 S.E. of the mean.

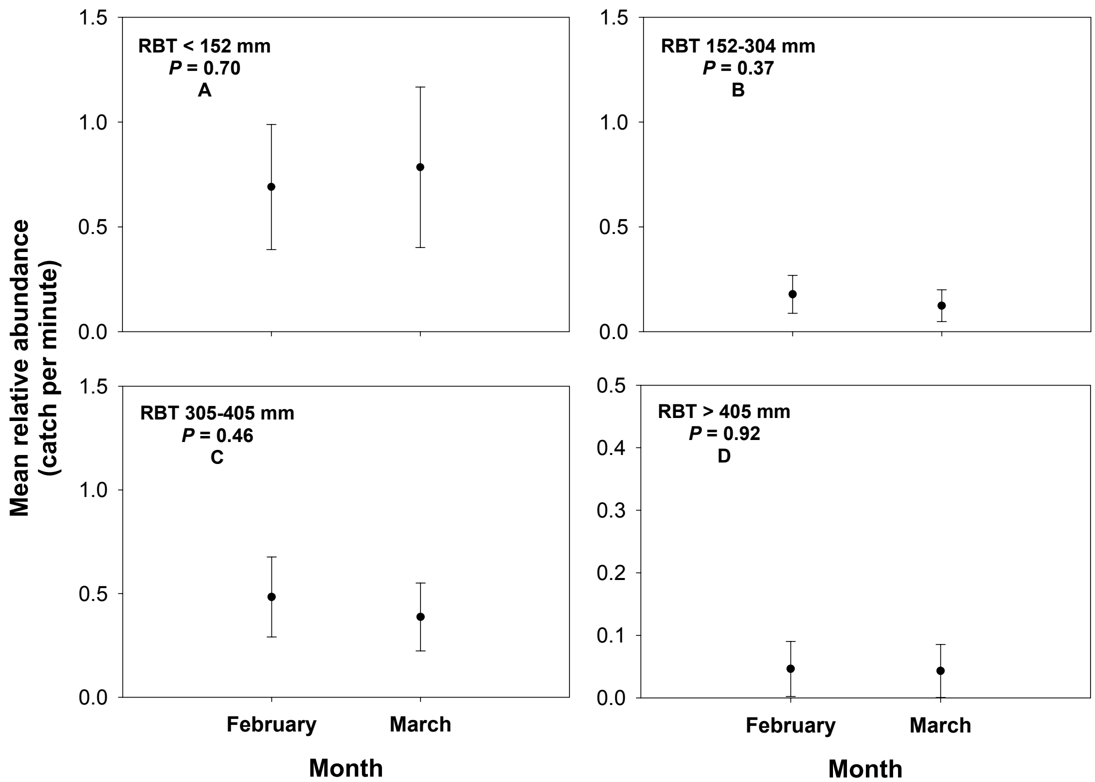

Figure 12. Rainbow trout mean relative abundance for fish < 152 mm total length (TL; panel A), 152-304 mm TL (panel B), 305-405 mm TL (panel C), and > 405 mm TL (panel D), in the Lees Ferry tailwater, February and March, 2008 (prior to and following a High Flow Experiment, respectively). Figure represents data from both fixed and random transects. Bars represent ± 2 S.E. of the mean. Note the scale difference on the y-axis on panel D.

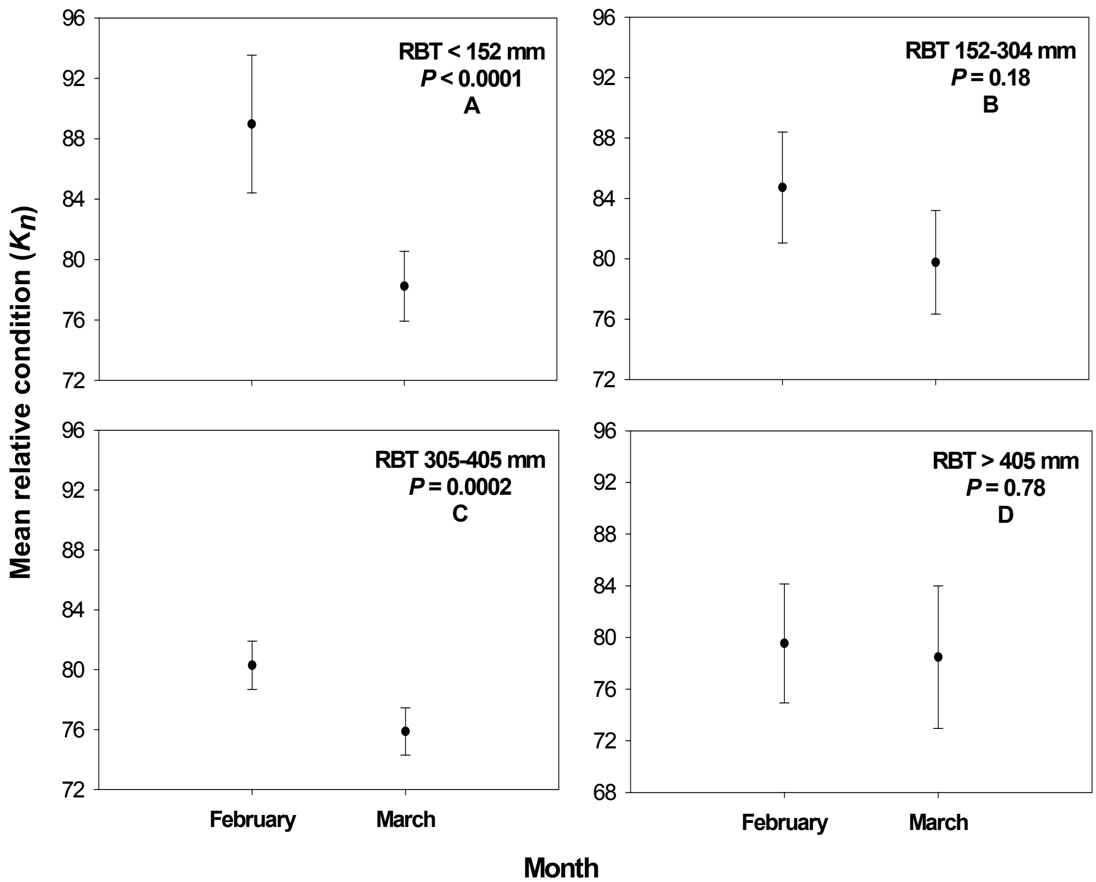

Figure 13. Rainbow trout mean relative condition (K_n) for fish < 152 mm total length (TL; panel A), 152-304 mm TL (panel B), 305-405 mm TL (panel C), and > 405 mm TL (panel D), in the Lees Ferry tailwater, February and March, 2008 (prior to and following a High Flow Experiment, respectively). Figure represents data from both fixed and random transects. Bars represent ± 2 S.E. of the mean.